The effect of annealing on the RHESSI gamma-ray detectors

P. Veres
Eötvös University, Budapest, Bolyai Military University, Budapesti, Hungary

J. Řípa
Charles University, Faculty of Mathematics and Physics,
Astronomical Institute,
Prague, Czech Republic

C. Wigger
Kantonsschule Wohlen, Switzerland

The performance of nine RHESSI germanium detectors has been gradually deteriorating since its launch in 2002 because of radiation damage caused by passing through the Earth's radiation belts. To restore its former sensitivity, the spectrometer underwent an annealing procedure in November 2007. It, however, changed the RHESSI response and affected gamma-ray burst measurements, e.g., the hardness ratios and the spectral capabilities bellow approximately 100 keV.

I. INTRODUCTION

The Ramaty High Energy Solar Spectroscopic Imager (RHESSI) [1] (http://hesperia.gsfc.nasa.gov/hessi) is primarily dedicated for studying solar physics in X-ray and gamma ray region. It's spectrometer [2] consists of nine germanium detectors, which are, however, only lightly shielded and thus also allow omni-directional gamma-ray burst (GRB) detection (http://grb.web.psi.ch) [3]. The energy range extends from 50 keV up to 17 MeV. The effective area reaches up to 200 cm^2. With a field of view of about half of the sky, RHESSI observes about 70 GRBs per year. It can detect all three populations of GRBs (long, short and intermediate) [4, 5].

II. THE ANNEALING PROCEDURE

In November 2007 the spectrometer underwent a procedure called annealing which was hoped to restore it's sensitivity that had been gradually deteriorating because of radiation damage [6]. It resided in heating up the germanium detectors to over 90°C for one week (operating temperature is about 90 K) [7] [8]. This procedure was successful only partly, because the low-energy response was not improved as well as the high-energy one. We have found that GRBs observed after the annealing have hardness ratio measurements systematically shifted to higher values that those observed before.

III. THE EFFECT OF ANNEALING ON HIGH-ENERGY INDICES

We used two spectral models for fitting GRB spectra. The Band function is of the form:

$$\frac{dN}{dE} \sim \begin{cases} E^{-\alpha} \exp\left(-\frac{E}{E_0}\right) & \text{if } E \leq E_{\text{break}} \\ E^{-\beta} & \text{if } E \leq E_{\text{break}} \end{cases} \tag{1}$$

The other model is the cutoff power-law (CPL):

$$\frac{dN}{dE} \sim E^{-\alpha} \exp\left(-\frac{E}{E_0}\right) \tag{2}$$

which is basically the low-energy part of the Band function with $\beta = \infty$

IV. THE EFFECT OF ANNEALING ON THE MEASURED HARDNESS RATIOS

Here we present the evolution of the average hardness ratios and their relation to the annealing. Figures 3 and 4 show the development of the average GRB RHESSI hardness ratios H21 and H32 over the years. H21 is a low energy ratio. It is the ratio of the GRB counts in the energy ranges (120 - 400)keV / (25 - 120) keV. H32 is a higher energy hardness ratio. It is the ratio of the counts in the ranges (400 - 1500) keV / (120 - 400) keV. Also the development of the average GRB T90 durations is shown (the plotted errors are 2 sigma). Emphasised are the data after the annealing realised in Nov 2007.

V. RESULTS AND CONCLUSION

From the figures it is seen that the observed GRB low energy hardness ratios H21 were systematically

TABLE I: Spectral fits of cutoff power law and Band function of some selected GRBs. The RHESSI off-axis angle for all these GRBs is near right angle.

GRB	model	data	α	β	E_p(keV)	χ_r^2
		Swift	1.37±0.02			1.27
061121	CPL	Konus*	1.32±0.05		606±80	1.01
		RHESSI	1.37±0.10		532±57	1.01
080607	CPL	Swift	1.15±0.03			0.70
		RHESSI	**2.33±0.18**		432±19	1.39
080825	Band	Fermi	0.54±0.21	2.29±0.35	180±23	1.23
		RHESSI	**5.36±0.86**	2.92±0.57	256±25	0.80

*GCN 5837

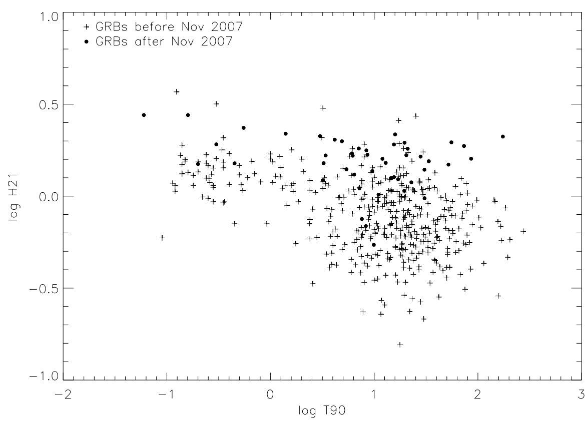

FIG. 1: The lower energy hardness ratio potted as function of the duration. Points after the annealing are systematically harder.

shifted to higher values after the RHESSI annealing in Nov 2007. Contrary to this the high energy ratio H32 remains, on average, the same. The T_{90} durations had not been affected.

We have also compared the spectral parameters of 3 GRBs. Whereas the low-energy photon index for the pre-annealing burst 061121, detected by Swift, Konus, and RHESSI, was found to be approximately the same, for the post-annealing bursts the situation is different. The RHESSI low-energy index for bursts 080607 and 080825 markedly differ from those obtained by the Swift or Fermi satellites.

This finding and the H21 systematic shift point to the fact that the RHESSI low energy sensitivity was not recovered well by the annealing procedure and using the RHESSI data for a future GRB spectral analysis, employing current response matrix, might be problematic.

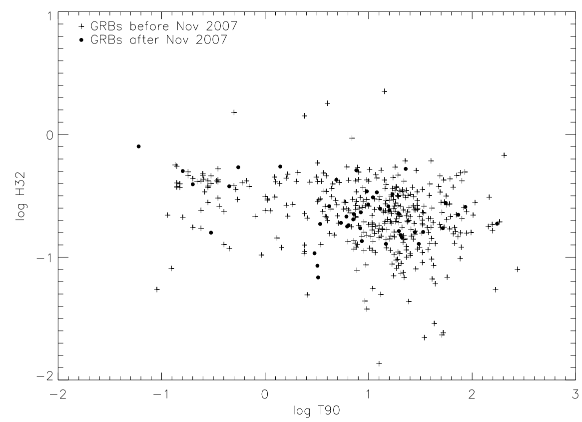

FIG. 2: The higher energy hardness ratio potted again in function of the duration. The effect of annealing is less evident.

Acknowledgments

This research is supported by Hungarian OTKA grant K077795 (P. V.), by the GAUK grant No. 46307, by the GACR 205/08/H005 grant and by the Research Program MSM0021620860 of the Ministry of Education of the Czech Republic (J. Ř.).

[1] Lin, R.P., et al. 2002, Solar Physics, 210, 3
[2] Smith, D.M., et al. 2002, Solar Physics, 210, 33
[3] Smith, D.M., et al. 2003, Proceedings of SPIE Vol. 4851, 1163
[4] Řípa, J., et al. 2009, Astronomy & Astrophysics, 498, 399
[5] Horváth, I. et al. 2006, Astronomy & Astrophysics, 447, 23
[6] Bellm, E. C., et al. 2008, AIP Conf. Proc., 1000, 154
[7] http://hesperia.gsfc.nasa.gov/hessi/news/jan_16_08.htm
[8] http://sprg.ssl.berkeley.edu/∼tohban/nuggets/?page=article&article_id=69

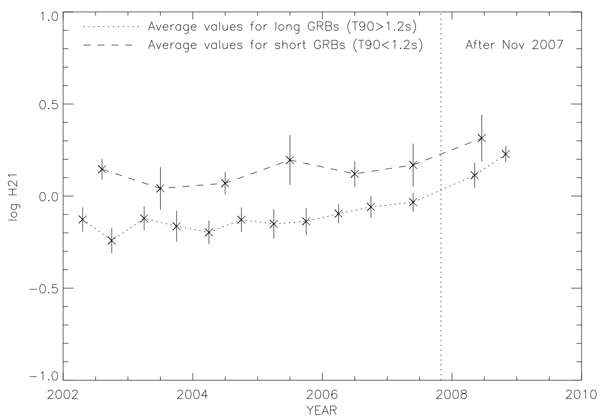

FIG. 3: The evolution of the lower energy hardness ratio in time for short- and long bursts. The vertical line marks the time of the annealing. An increasing trend is clearly seen.

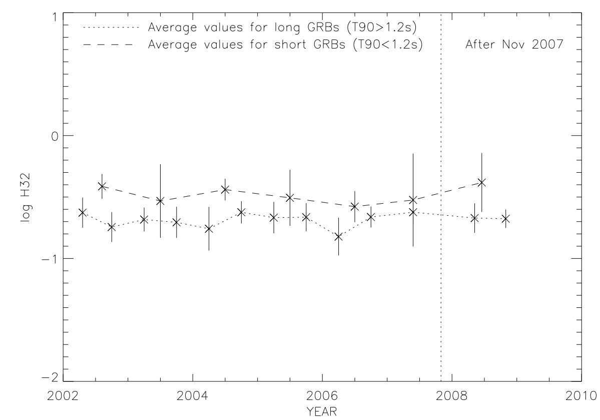

FIG. 4: The evolution of the higher energy hardness ratio in time for short- and long bursts. There is no significant difference between the pre- and the post annealing phase.

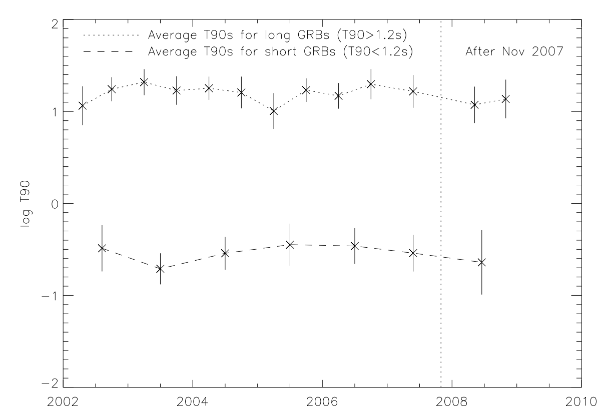

FIG. 5: Average T_{90} for long- and short GRBs.